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CSIMPS: A PROGRAM FOR DERIVING ASTEROID DIAMETERS AND ALBEDOS FROM IRAS DATA

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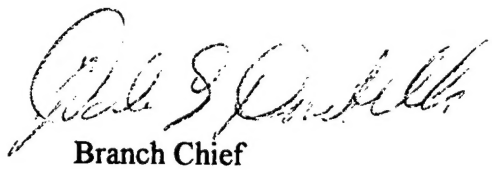

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ABSTRACT *(Maximum 200 words)*

The primary goal of CSIMPS is to obtain derived information concerning asteroids with reliable orbital elements. From a database of probable sightings extracted from IRAS data, the orbital elements of a known asteroid can be used to find IRAS sightings of that asteroid. Together with prior observations of the asteroid's absolute magnitude, and slope parameters the asteroid's albedo and diameter can be derived from the IR flux of the IRAS sighting. Supplementary derived information, including quality metrics, both enhance the scientific value of these derived parameters and are useful for evaluating the completeness and accuracy of the data reduction routines.

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1 About CSIMPS

The primary goal of CSIMPS is to obtain derived information concerning asteroids with reliable orbital elements. From a database of probable sightings extracted from IRAS data, the orbital elements of a known asteroid can be used to find IRAS sightings of that asteroid. Together with prior observations of the asteroid's absolute magnitude, and slope parameters the asteroid's albedo and diameter can be derived from the IR flux of the IRAS sighting. Supplementary derived information, including quality metrics, both enhance the scientific value of these derived parameters and are useful for evaluating the completeness and accuracy of the data reduction routines.

CSIMPS processes two databases: 1) the probable sightings extracted from IRAS database (IP01A) and 2) the known asteroid orbital elements database (IP03.bin).

The IP03.bin database contains, for each known asteroid, the osculating orbital elements for each of three epochs in 1983; the UBV color indices, the absolute magnitudes and the geometric albedo. These values were compiled from many locations, mostly from ground observations.

The IP01A database contains about 2.7 million probable sightings extracted from the IRAS Survey data during the confirmation strategy processing phase. The confirmation strategy separated IR sources into three basic categories: fixed sources, non-astronomical sources such as energetic particle hits and fast-moving debris, and moving sources such as asteroids and comets. The processing involved comparing detections in two contiguous detectors of a single scan, in two or more orbits within a 36-hour period, and scans taken several weeks apart. This processing was limited to some extent by background regions where a moving source's short wave signature could be lost in the structured signatures of the galactic center, Magellanic clouds, or the source's long wave signature could be lost in the celestial cirrus. Thus, these sightings do not represent a uniform spatial sampling of the whole sky. Nonetheless, these IRAS survey observations, which began February 9, 1983 and ended November 22, 1983, remain the most complete IR survey of asteroid properties made to date. The IP01A database is said to be the final probable sightings database that will be extracted from the IRAS data.

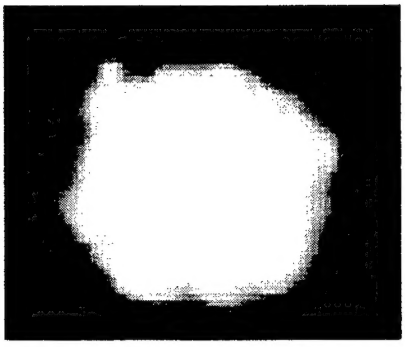

Figure 1: CSIMPS estimates the diameter of Eugenia to be 214.63 ± 4.2 km. Other measurements set the diameter to be 226 km. Composite image of 45 Eugenia and its moon at upper left made from 15-second exposures on the CFHT in November 1998, image from web site:
http://nssdc.gsfc.nasa.gov/planetary/news/eugenia_pr_19991006.html

1.1 The Distribution

The CSIMPS CD has the following directories:

CSIMPS	The Suite of CSIMPS processing routines and data files required to run the codes.
CSIMPS_Dev	The Software used to build the CSIMPS programs, and Microsoft Visual C++ and Compaq Visual Fortran Project Workspaces for building the codes.
CSIMPS_Doc	Documentation including final report, user's manual, and CSIMPS catalogs.
Ip_data	The IRAS Probable Sightings database.

1.2 Installation

To install the software for running on your local Windows machine, simply copy the CSIMPS directory to your hard disk as a top level directory. [Note: CSIMPS has only been tested for Windows NT.] There are no GUIs or other applications that would require updating your Windows registry. If your system has a lot of free disk space, and copying the 397 Mbytes ip_data folder will not impact space requirements, then copy the ip_data folder to your hard disk for faster processing. It is not necessary to copy this folder to the hard disk, because the program can access it directly from the CD.

The source code and build files for MS Visual C++ (Visual Studio) and Compaq Visual FORTRAN are included and the software can be rebuilt for different platforms.

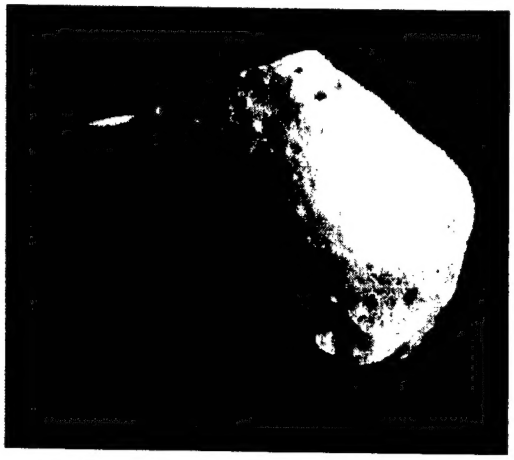

Figure 2: CSIMPS estimates the diameter of Mathilde to be 58.05 ± 2.6 km. This is a mosaic of the main belt asteroid 253 Mathilde made up of four images returned by the NEAR spacecraft during its flyby. The images were taken on 27 June 1997 from a distance of 2400 km. The portion of the asteroid visible is about 59 x 47 km and the resolution is roughly 300 m. Three large craters can be discerned, one at lower center, one at the top left viewed edge-on, and one at lower right, also viewed edge-on. The crater at center is estimated to be 10 km deep. These large craters, the abundance of smaller craters, and the angular shape point to a history of heavy bombardment. Lighting is from the upper right. (NEAR Mathilde 199706271400) Image from: http://nssdc.gsfc.nasa.gov/imgcat/html/object_page/nea_19970627_mos.html

1.3 CSIMPS Directory Hierarchy

The distribution directory hierarchy is:

CSIMPS\

\AD_database	Holds the output files of the AD (derived asteroid information) programs
\AK_Proc_Param	Contains the AKM.EXE input file KapNam.txt.
\AK_database	Holds the output files of the AK (sighings associations and missed predictions of the known asteroids) data.
\Asteroid_Elements	Contains the input files for generating the IP03.bin file of known asteroid osculating elements and other parameters.
\Bin	Contains all the CSIMPS programs.
\Final_Products	Holds the output files of the FP (Final Product) generation programs.
\IPAC	Contains input data files from IPAC. These are used during the AK processing.
\IP_database	Contains input files IP01A.Loc which points to the IP01A and IP01Andx files, which are so large they can be accessed from the CD or copied to the hard disk.

The distribution includes all the output files that were generated when running the entire suite of programs on the current asteroid elements files.

1.4 Before Running the Codes

First, run the \CSIMPS\Clean.bat batch file to remove the output files of the last run.

Second, edit the IP_database file IP01A.Loc. The IP01A file is the IRAS database of probable asteroid sightings. This file contains the full filespec (drive, path, filename) of the IP01andx and IP01a files. Combined, these files are over 397 Mbytes. The distribution entries are:

\ip_data\ip01andx

\ip_data\ip01a

which are set for the ip_data directory to be a top-level directory on the same drive as the CSIMPS top level directory. Edit these names to indicate the drive and location of the data files.

Third, if you have new asteroid osculating elements and associated data, it needs to be put into the same format as the \CSIMPS\Asteroid_Elements\ET*.dat format and you need to replace those four files with yours and edit the IADK.DAT file to have the number of entries in those files.

1.4.1 ETELEMS<1-3>.DAT File Format

The ETELEMS data files have one record (text line) for each asteroid. There are three files so that each asteroid has three sets of B1950 osculating orbital elements. The text line format is (note: the third unknown value is not used in the CSIMPS suite):

Variable	Description	Units	Format
Class	Asteroid Type	None	I*1
AAGID	Known Asteroid Number	None	I*6
?	?	?	I*2
Name	Character String Assigned to Identify a particular asteroid.	None	Char*16
EpnUT[n]	Time of Perihelion Passage.	Julian Date in Days	F13.5
Apn[n]	Argument of Perihelion	Degrees	F12.7
Lan[n]	Longitude of Ascending Node	Degrees	F12.7
Incl[n]	Inclination	Degrees	F12.7
En[n]	Eccentricity	None	F12.9
PDn[n]	Perihelion Distance	AU	F12.9

The n in the above table is the Epoch given by:

Julian Date	Gregorian Date
2445200.5	7 Mar 1983
2445500.5	15 June 1983
2445600.5	23 September 1983

Here is a partial listing of the ETElems Files showing the field locations and lengths within the text line:

```
 class
|     AAGID  Name              |  EpnUT[1]      Apn[1]      LAn[1]      Incl[1]     En[1]       PDnKm[1]
||   |     |                  | ||          ||          ||          ||          ||          ||          |
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123
          1         2          3          4          5          6          7          8          9         10
1     1 1  Ceres           2444788.11976  73.1988620  80.0517697  10.6063282 0.078516600 2.548919000
1     2 1  Pallas          2444834.46074 310.0015775 172.6826518  34.7890752 0.232855700 2.127191800
1     3 1  Juno            2445699.44044 247.0303658 169.8859653  13.0024157 0.257399500 1.981633400
1     4 1  Vesta           2444990.52492 150.2300017 103.4395875   7.1427010 0.089158000 2.150999400
1     5 1  Astraea         2445332.12583 355.8404930 141.2483334   5.3485821 0.188073100 2.092045400
```

1.4.2 ET_ADD.DAT File Format

There is a corresponding ET_Add.Dat data file that has one record (text line) for each asteroid. This file contains data describing the known magnitude, diameter, and other information. The text line format is (note: the unknown values are not used in the CSIMPS suite):

Variable	Description	Units	Format
Class	Object Type	None	I*1
AAGID	Known Asteroid Number	None	I*6
Name	Character String Assigned to Identify a particular asteroid.	None	Char*16
H	Absolute Visual Magnitude	Mag	F5.2
G	Phase-Like-Coefficient Parameter	None	F6.3
Alb	ADAS Albedo	None	F5.3
D	Diameter	KM	F5.1
?	?	?	I*1
?	?	?	I*1
ERC	Ephemeris Reliability Code	None	I*1
IRAS1	IRAS ADAS FP04 Code 1->Included	None	I*1
CSC	Class Source Code	None	I*1
?	?	?	I*1
?	?	?	I*1

Here is a partial listing of the ET_ADD.DAT file showing the field positions and lengths within a record:

```
                                                EIC
                                                RrS
                                 H      G     Alb     D    CaC
                                 |      ||     ||     | |    | |||
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012
         1         2          3         4         5         6         7
1    1    Ceres              3.34   0.12 0.100 910.0331331
1    2    Pallas             4.13   0.11 0.140 521.0331331
1    3    Juno               5.33   0.32 0.220 243.0331331
1    4    Vesta              3.20   0.32 0.380 500.0331331
1    5    Astraea            6.85   0.15 0.140 124.0231231
```

2 How to Run The Code

The CSIMPS processing is run by running four batch files in sequence from the \CSIMPS directory:

PreProcess.Bat

AK_Proc.Bat

AD_Proc.Bat

Create_FinalProducts.Bat

2.1 The Asteroid Elements Preprocessor

The PreProcess.Bat file runs the \CSIMPS\bin\genip03.exe program. This program takes as inputs the ETELEMS1.DAT, ETELEMS2.DAT, ETELEMS3.DAT, ET_ADD.DAT and iadk.dat files and produces the ip03.dat file and the Ranges.Dat file. Together, the IP01A file and the IP03.dat file are the major input files to the CSIMPS suite.

2.2 The AK Processing Routines

The AK_Proc.Bat file runs the following sequence of codes:

bin\akm

bin\genak04

bin\genak09 /auto

bin\genak06 /auto

bin\genak05 /auto

bin\rdak05

bin\genak10 /auto

bin\Add2AK10 /auto

bin\StatStat /auto

bin\IMPSUt01 /auto

bin\IMPSUt02 /auto

bin\GenAK11 /auto

Collectively, these codes make up the AK processor. They take as inputs the IP01A file, the IP03.bin file, the Ranges.Dat file, files in the IPAC subdirectory which describe the IRAS data, and the KapNam.txt file in the AK_Proc_Param subdirectory.

The AK processor first makes sightings predictions for the IRAS survey times based on the osculating elements of known asteroids (from IP03.bin) and then classifies IRAS probable sightings (from IP01A) as either associated or disconnected, and classifies predicted sightings as either associated or missed. From there, the associated sightings (a predicted sighting that matched an IRAS probable sighting) and the missed predictions (a predicted sighting that did not match an IRAS probable sighting) are processed separately. The output files produced are written to the AK_database directory. The tables below describe the contents of the major files.

Additional log files are in text format and are for the most part self-explanatory when viewed with a text editor.

Table 1: The AK Processing Output Files of the Associated Sightings

Filename	Description
AK01.bin	Sightings associated with known asteroids. Predicted sightings are derived from the IP03 asteroid elements. The IP01A file is searched for possible associations.
AK13.txt	"Disconnected" asteroids. A record is written whenever an asteroid is associated with a sighting that has previously been associated with a different asteroid.
AK04.txt	Sightings associated with known asteroids. This file has the same sightings as the AK01 file, and includes additional descriptors.
AK06.bin	For each asteroid, there is a record holding pointers to all the associated sightings, and pointers to all the missed predicted sightings.
AK05.bin	Sightings associated with known asteroids.

Table 2: The AK Processing Output Files of the Missed Predictions

Filename	Description
AK02.bin	Missed predicted sightings. Predicted sightings are derived from the IP03 asteroid elements. The IP01A file is searched for possible associations. Reference PL-TR-92-2049, "The IRAS Minor Planet Survey" Chapter 4, page 28 and 36: Predicted sightings which were not realized were recorded in AK02; this included sightings which were actually impossible because, for example, the source was too faint or the image crossed dead detectors, etc.
AK09.txt	Missed predicted sightings file.
AK06.bin	For each asteroid, there is a record holding pointers to all the associated sightings, and pointers to all the missed predicted sightings. These pointers reference data in AK10.bin.
AK10.bin	Missed predicted sightings file.
AK11.txt	Missed predicted sightings file.

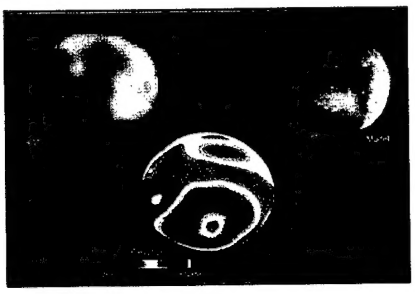

Figure 3: CSIMPS estimates the diameter of Vesta to be 468.30 ± 26.7 km.

Image, elevation map, and model Vesta's surface.
Image from :
http://nssdc.gsfc.nasa.gov/photo_gallery/photogallery-asteroids.html

2.3 The AD Processing Routines

The AD processor calculates the radiometric diameters and geometric albedos and their uncertainties (i.e., Asteroids, Derived parameters). Albedos and diameters are computed for each known object by applying the same algorithm to each detection in any survey band. The inputs files are the AK_database files and some of the AK input files (e.g., IP03.dat and the thermal IPAC data). The results are then averaged for each object, after applying additional acceptance criteria. Outputs of the AD Processing are written to the AD_database subdirectory. The major files and their descriptions are listed below. Additional log files are in text format and are self-explanatory.

File	Description
AD06.bin	Computed albedos and diameter for each missed sighting in AK10.bin.
AD02.bin	Computed albedos and diameter for each associated sighting in AK05.bin.
FP01A.bin	Averaged albedos and diameters for all accepted sightings for each asteroid.
AD07.txt	Computed albedos and diameter for each missed sighting.
AD04.txt	Computed albedos and diameter for each associated sighting.

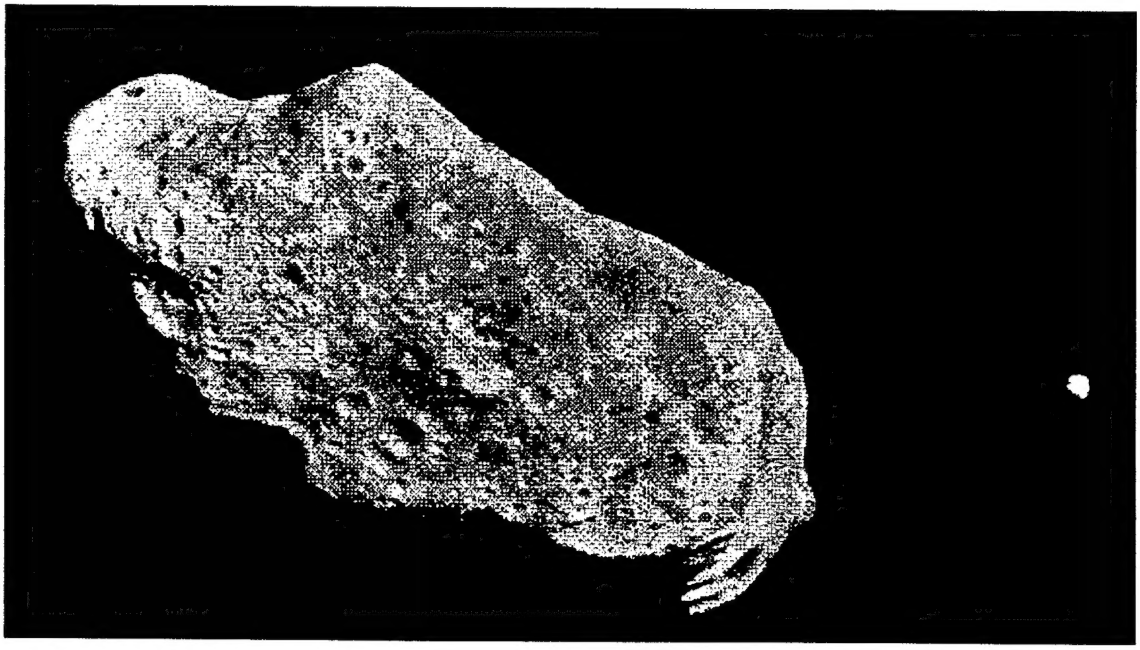

Figure 4: CSIMPS estimates the diameter of Ida to be 27.99 ± 3.2 km. The second of the two asteroids which Galileo encountered en route to Jupiter, Ida was discovered to have something different: its own satellite! Galileo's flyby of Ida (and its moon Dactyl) occurred on 28 August 1993 at a distance of about 2,400 km. This image shows the asteroid Ida and its moon, Dactyl (in false color). Image from: http://nssdc.gsfc.nasa.gov/photo_gallery/photogallery-asteroids.html

2.4 The FP Processing Routines

The Final Product (FP) processing generates a series of text files that are catalogs of asteroid data. The inputs are the AK_database, the AD_database, the Asteroid_Elements files, the IP01A IRAS Sightings files, and other IPAC files. The outputs of the FP Processing are written to the Final_Products subdirectory. The major files and their descriptions are listed in the table below. Additional log files are in text format and are self-explanatory.

File	Description
FP202.txt	CSIMPS Albedos and Diameters Catalog. Averaged Values for all asteroids having two or more accepted sightings.
FP203.txt	CSIMPS Singleton Catalog. Derived albedos and diameters for all asteroids, which have only one accepted sighting in a single band.
FP205.txt	CSIMPS Reject Catalog. A summary of the number of rejected sightings for each asteroid and the possible reasons for rejection.
FP206.txt	CSIMPS Missed-Predictions Catalog. A summary of those asteroid which were predicted to pass across the IRAS focal plane during survey mode, but which generated no accepted associations.
FP208A.txt FP208B.txt FP208C.txt	CSIMPS Sightings Database. A summary of accepted sightings with their associated asteroid; the predicted and observed locations, times, and fluxes; the derived albedo, diameter, and uncertainties; quality metrics and status words.
FP209A.txt FP209B.txt FP209C.txt	CSIMPS Rejected Sightings Database. A summary of rejected sightings, that were processed to AD02.bin but later rejected, with their associated asteroid; the predicted and observed locations, times, and fluxes; the derived albedo, diameter, and uncertainties; quality metrics and status words.
FP220A.txt	CSIMPS Catalog of all asteroids, number of sightings, number of missed predictions, average albedo and diameter, etc.
FP221A.txt	Final OR'd Asteroid Status Word for all asteroid sightings in the AK05.bin file.

There are some additional modes of operation for the AK processing routines. The nomenclature of the routines indicates the file(s) that they produce. It is important to delete the current output file from the Final_Products directory, or the file might be appended. To see the optional command line inputs type for example:

```
CSIMPS>bin\genfp105 /?
```

The console output is as follows:

```
Genfp105: start time 8/10/2000 22:37:9
```

Usage:

```
bin\genfp105 [/auto] [/cat] [First AsteroidID] [Final AsteroidID]
```

In "/auto" mode, the program reads Ranges.Dat and uses those asteroid ID ranges and sightings ranges for processing. Without that, the code prompts the user for a starting and final asteroid ID for inclusion in the output file. Optionally, the user may input that on the command line. The /cat option, produces a text file in the catalog format prescribed by the "IRAS Minor Planet Survey." This format includes the title, beginning text, and tabulated values with table headings. By importing the text file into a word processor and selecting Courier type (non-proportional spacing) 8-point fonts, a nice catalog is quickly generated. The page breaks are already included. To get a two column format, select the catalog tables, and format the pages for two columns then do a "find and replace" operation replacing the manual page breaks with manual column breaks.

3 Using the Output Data

The CSIMPS catalogs are useful for gaining a statistical picture of the spatial distribution of asteroids and their properties. The catalogs can be used to produce scatter plots of albedo vs. diameter, diameter vs. ecliptic latitude and longitude, histograms of albedos or magnitudes, etc.

The data can be compared to other observations. Below, the derived diameters from the FP202.txt catalog are compared to measured diameters for a handful of asteroids:

AsteroidID	Name	Diameter (km)	CSIMPS Diameter (km)	CSIMPS Sigma-Diameter (km)
1	Ceres	960 x 932	848.40	19.7
2	Pallas	570 x 525 x 482	498.07	18.8
3	Juno	240	233.92	11.2
4	Vesta	530	468.30	26.7
45	Eugenia	226	214.63	4.2
140	Siwa	103	109.79	3.0
216	Kleopatra	217 x 94	135.07	2.1
243	Ida	58 x 23	27.99	3.2
253	Mathilde	66 x 48 x 46	58.05	2.6
1620	Geographos	2.0	1.77	0.1

Reference for Galileo website
http://nssdc.gsfc.nasa.gov/planetary/factsheet/asteroidfact.html.